ENGINEERING CASE LIBRARY

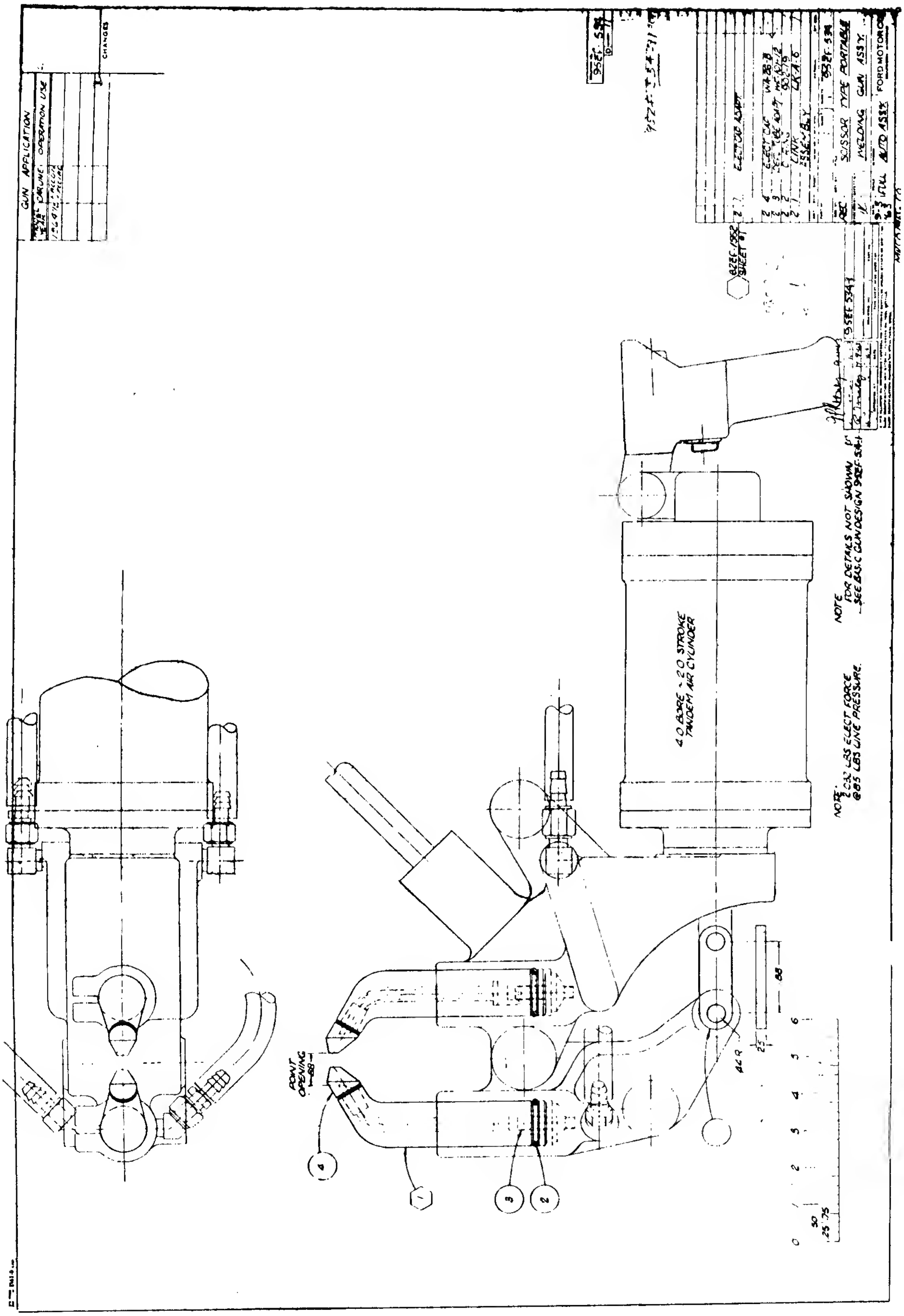
EGL 53A

Design of an Automatic Welding Machine

At Ford Motor Company, San Jose, California (A)

In May 1964, Ray Rogers, a Tool Design & Process Engineer, and Bill Fleming, Weld Engineer at the San Jose Assembly Plant of the Ford Motor Company in Milpitas, California, were assigned to design an automatic welding machine. The equipment was to place a series of spot welds along the rocker panel flanges of a new model for the Mustang, in place of the manual welding accomplished by a man on each side of the body construction line for the previous year Fairlane model.

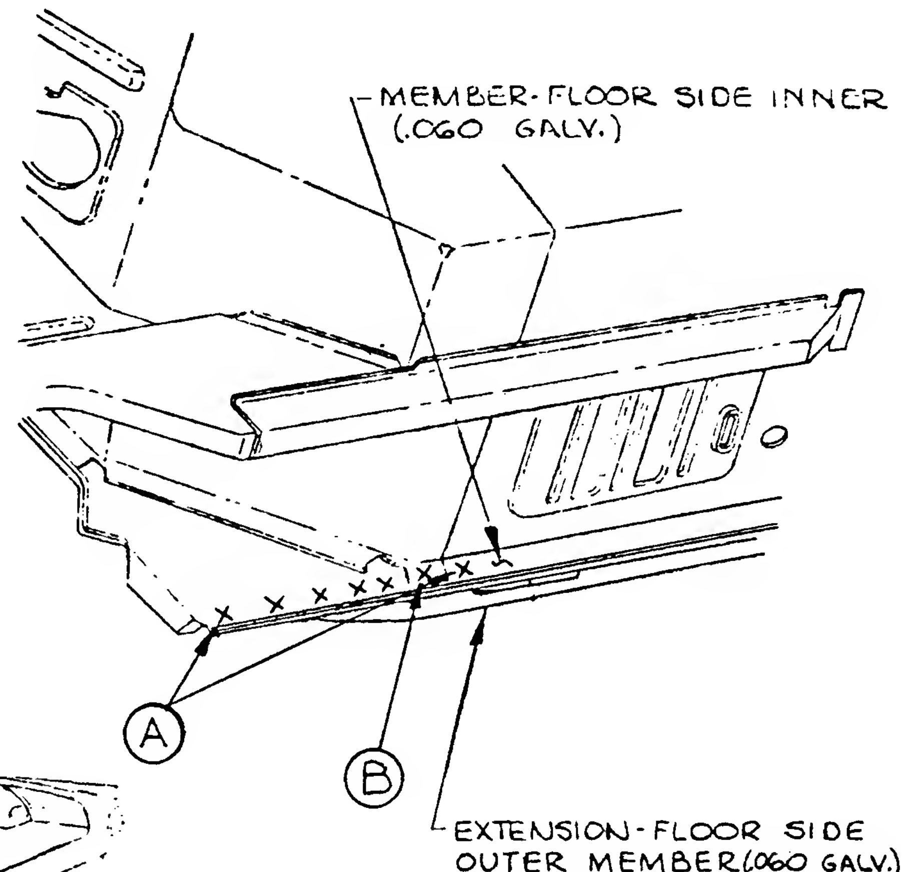
Written by John Alic with support from the National Science Foundation. The cooperation of Mr. J. McLean, Mr. R. Rogers and Mr. W. Fleming of the Ford Motor Company are gratefully acknowledged.



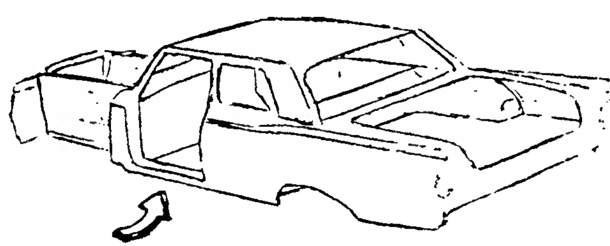
Hand-Held Weld Gun

ORIGINAL ISSUE DATE - 12-2-63		
DATE	REVISION	LINE
	CARRYOVER REV. 1965	
12-1-6[illegible]	REVISED TO INCLUDE MODELS. 65 B-C & 63 H-B	B-25

REF.: WS.M. PAGE W5-8304 2 of 4



WELD INFORMATION	
SECONDARY AMPERES	15000
ELECTRODE FORCE	1600#
WELD TIME	18~
BUTTON FEAT SET-UP	.31
MINIMUM BUTTON SIZE	.26

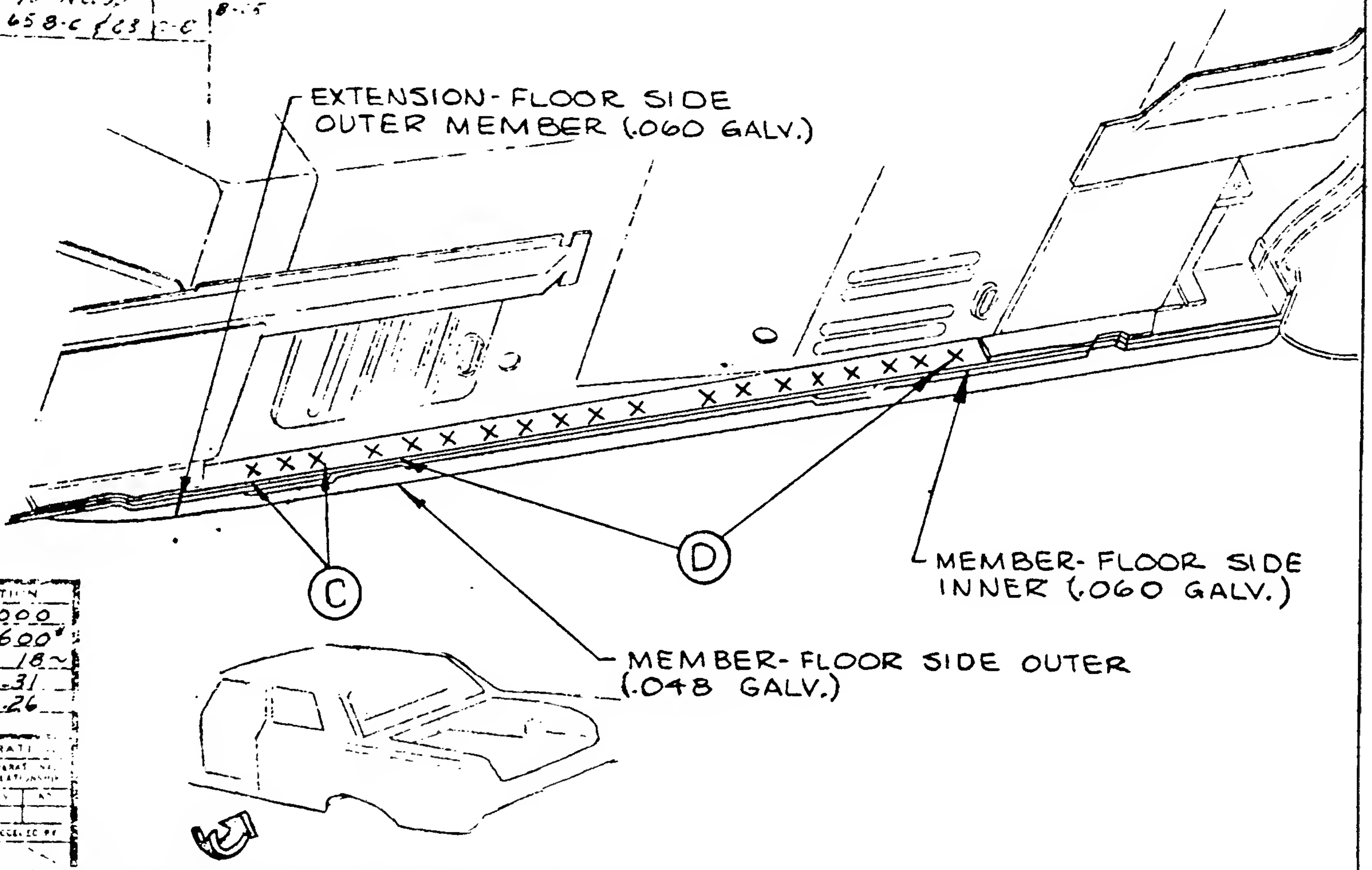


952F-534-11	PORTABLE SPOTWELD GUN (DUAL SCHEDULE)	1	POSITION SPOTWELD GUN AND SPOTWELD
		2	EXTENSION-FLOOR SIDE OUTER MEMBER
		3	TO
		4	MEMBER-FLOOR SIDE INNER
		5	WITH
		6	(A) (6) SPOTS EACH SIDE AS SHOWN
		7	MEMBER-FLOOR SIDE INNER AND PANEL-DASH WITH
		8	
		9	(B) (1) SPOT EACH SIDE AS SHOWN
		10	
		11	
		12	CONTINUED ON SHEET #2

Process Sheets for Rocker Welding on Mustang Hardtops. 1 of 3

ORIGINAL ISSUE DATE - 12-2-63		
DATE	REVISION	LINE
	CARRYOVER REV. 1965	
11-1-19	REVISED TO INCLUDE MODELS 65 8-C & 63	

REF: W.S.M. PAGE W5-8304 2 of 4



WELD INFORMATION	
SECONDARY AMPERES	15000
ELECTRODE FORCE	1600#
WELD TIME	18~
BUTTON SIZE AT SET UP	.31
MINIMUM BUTTON SIZE	.26
TIP DRESSER	

15	952F-534-11	PORTABLE SPOTWELD GUN (DUAL SCHEDULE)	1	
16			2	
17			3	
18			4	EXTENSION-FLOOR SIDE OUTER MEMBER
19			5	AND MEMBER-FLOOR SIDE MEMBER
20			6	WITH
21			7	Ⓒ (3) SPOTS EACH SIDE AS SHOWN
22			8	MEMBER-FLOOR SIDE OUTER
23			9	TO
24			10	MEMBER-FLOOR SIDE INNER
25			11	WITH
26		CONTINUED ON SHEET #3	12	Ⓓ (16) SPOTS EACH SIDE APPROX. 2.0" APART

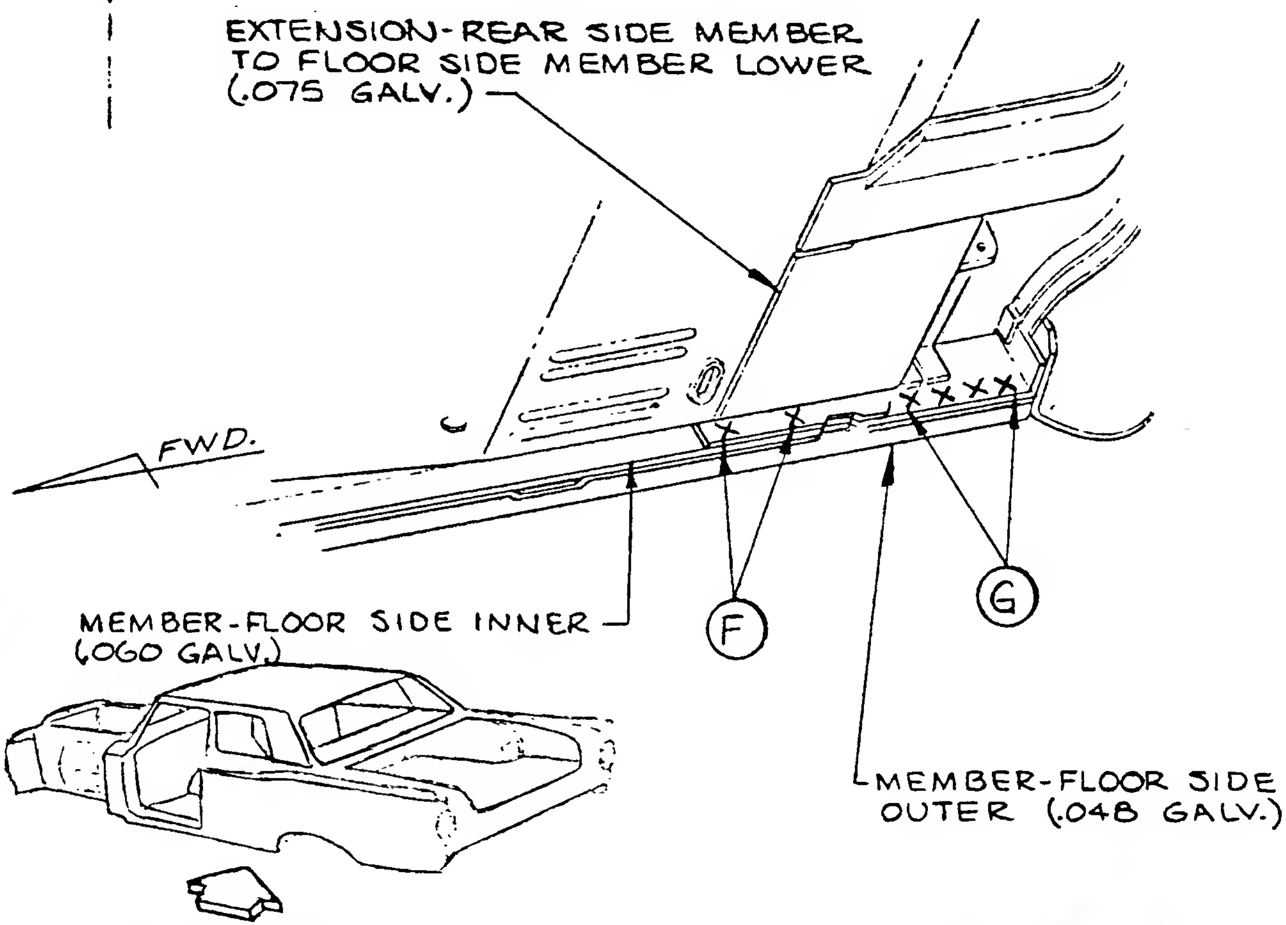
Exhibit 2

ECL 53A

ORIGINAL ISSUE DATE	12-2-63	
DATE	REVISION	LINE
	CARRYOVER [illegible]	
9-1-64	REVISED TO INCLUDE MODELS 65 2-C & 63 A-B	

8-25

REF.: W.S.M. PAGE W5-8304 2 OF 4



WELD INFORMATION	
[illegible]	15000
[illegible]	16.00#
WELD TIME	18~
BUTTON SIZE AT SET UP	.31
MINIMUM BUTTON SIZE	.26
TIP DIA.	

KEY PROCESS OPERATION

15	95ZF-534-11	PORTABLE SPOTWELD GUN	1		MEMBER-FLOOR SIDE INNER AND
16		(DUAL SCHEDULE)	2		EXTENSION-REAR SIDE MEMBER TO
17			3		FLOOR SIDE MEMBER LOWER
18			4		WITH
19			5	F	(2) SPOTS EACH SIDE AS SHOWN
20			6		MEMBER-FLOOR SIDE INNER
21			7		WITH
22			8	G	(4) SPOTS EACH SIDE AS SHOWN
23			9		
24			10		COMPLETES WELDING OPERATION
25			11		A7-90
26			12		

Exhibit 3

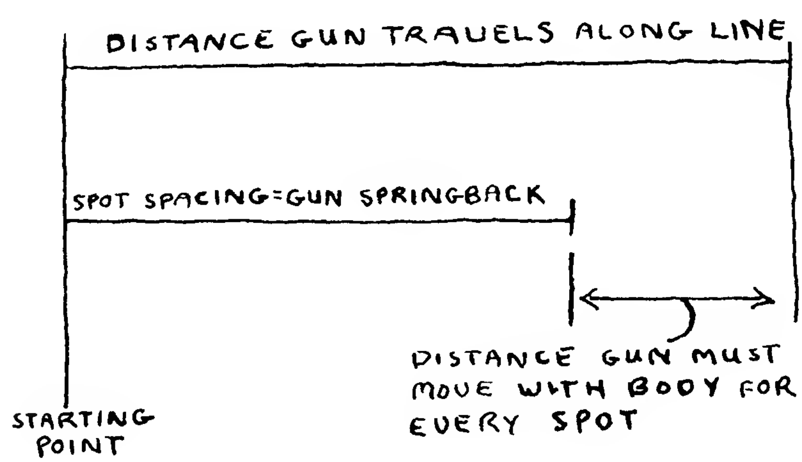
Transfer of a Mustang Body

Design of an Automatic Welding Machine

At Ford Motor Company, San Jose, California (B)

The first rocker welding machine Ray drew up is shown in Exhibit I. Notes have been added to the drawing. He completed the design in June 1965, first working out the ideas in sketch form and then making this layout. The drawings show one of the four independent machines he planned to have built; two would be placed on each side of the car. Each machine would carry one weld gun, of the model specified in the process sheets, mounted on a pivot allowing it to swing upwards and clamp onto the rocker. A roller is fitted on each side of the electrodes; the rollers bear against the bottom of the rocker flange while a spring holds the gun in the up position. To retract the gun, an air cylinder is actuated which forces the gun to pivot against the spring, out of the way between cars. The cylinder is controlled by limit switches which detect bodies entering and leaving the weld area.

The gun is carried on longitudinal shafts and ball bushings and allowed to move parallel to the rocker with restraining counter travel springs. After the electrodes clamp onto the rocker, the moving car draws the gun along with it. When the electrodes release, the springs return the gun to its original position. The carriage of the machine -- the weld gun and its mountings -- can also move a limited distance in the direction perpendicular to the rocker panel, again on ball bushings. The carriage can also move parallel to the car on trolley wheels against the resisting force of an air cylinder. Ray was going to use this cylinder to allow incremental motion of the gun, so that it could keep up with the line. He was planning to use the first of the two machines on each side of the car to put in the first 16 spots, spaced at 2 inches, with the other machine picking up where the first left off and continuing. This is the same pattern used for hand welding. However, at 57 cars/hour and 2 inch spacing he found that the machines would not be able to keep up unless they moved along with the cars. Ray diagrammed the situation as below:



The gun springs back on its ball bushing mount a distance equal to the spot spacing (disregarding the distance the car moves during springback). To keep up, the wheeled carriage must move against the air cylinder an amount controlled to give the proper weld spacing.

The air cylinder is used with a pressure regulator and a flow control valve as diagrammed in Exhibit 2. The pop-off valve is set to release the air in the cylinder at a certain pressure. It acts as a safety valve; if the electrodes on the weld gun refuse to open, the valve will blow and allow the carriage to move along with the car. The flow control valve allows free flow into the cylinder but restricts flow outwards. The flow out is adjustable and the valve can be set, by trial and error, to allow the carriage to be pulled along in repeatable increments. Ray calculated that the gun would have to increment 1-1/4 inches with every weld at 57 cars/hour and thus that he needed an air cylinder at least 1.25 inches x 20 spots* = 25 inches long. He specified a 25 inch cylinder. When the 16 welds are completed and the gun is at the end of its travel, a limit switch actuates a valve through a solenoid, the air flow to the cylinder is reversed, and it pushes the carriage back to its starting point.

When the Mustang line was first started up in June, the rocker welds were put in by men with hand-held guns of the type specified on the process sheets (see Exhibit 1 of part A) in a pit about 4 feet deep just past the transfer table. A plan view of the

* 16 spots are the required minimum Ray decided to allow for more welds per car.

arrangement is shown in Exhibit 3. When he found that the machine would be used in a pit Ray had to design a framework to support it. However, it was found difficult to position the electrodes of this gun correctly on the section of the rocker adjacent to the seat riser. The seat riser is a depression in the floor pan which extends almost to the strip of metal which had to be welded. This weld gun had a movable back jaw. When the jaw was in the open position, before or after being clamped onto the rocker, it interfered with the seat riser. It was very hard to position the gun by hand in the seat riser area; Ray thought that it would be impossible to do by machine and his first design (Exhibit I) was never built.

Ray believed that he could eliminate the problems by using a gun on which the front jaw opened. The model he wished to use could not take enough current, but Bill Fleming thought he would be able to modify it by water cooling the shunt. Ray then started a new design, shown in Exhibit 4, on an overlay so that he would not have to redraw the unchanged portions. The carriage of this machine can also move parallel to the line both on ball bushings which carry the gun and on trolley wheels at its base. A 25 inch air cylinder is again used. The gun is now held up against the rocker by a counterweight instead of by a spring.

When Ray had this design almost completed, one of his supervisors told him to change it so that only one machine per side, with a single gun, would be needed. The only change Ray found necessary was to increase the length of the travel control

air cylinder to 40 inches. Bill calculated that he would have to double the current carrying capacity of the cables to the weld gun to allow 32 successive welds without overheating. The decision to use one machine per side was rescinded before fabrication actually started, however, and the machines were all built with 25 inch cylinders. With two machines on each side of the car, one could still be operated if the other was shut down for maintenance or repair. The electrodes of the weld guns must be replaced frequently; with two machines per side the line would not have to be stopped for such routine tasks. Management decided that the advantages in flexibility that would accrue from the use of four machines outweighed the added cost.

The electrical control circuitry was Bill's responsibility. He designed the controls so that, in addition to starting and stopping the cycle and detecting convertibles and hardtops, it would:

-- cause the gun to drop away from the rocker should there be a power failure.

-- shut off the gun and attempt to retract it from the rocker if the electrodes would not open.

-- shut down the line (stop the cars from moving) if the gun would not retract at all.

-- shut off current to the gun but not retract it if the lines were shut down intentionally (at lunchtime, for example). This was to ensure against missing a weld when the line was restarted.

He used separate but identical control circuits for all four machines so they would be independent.

Ray completed the final design in September. Before construction of the machines began, management had to approve the expenditures. Then the purchased parts were ordered. The first machine was installed in the pit in November. In the design of the machine Ray had provided various means for alignment and adjustment. He recalled that it took more than a week to get the first machine correctly set up, but that when this was accomplished it functioned satisfactorily except for over-heating of the weld gun body. At this time the line was running at 36 cars/hour and the one machine was putting in all the welds on one side of the car. Ray and Bill solved the overheating problem by adding a water jacket to the gun body. The other three machines had been finished but their installation was not completed until several months later. Ray explained that there was not time to get them running immediately because of pressures from other jobs connected with the Mustang startup program. Ray and Bill recalled several instances during these months when they spent as much as 20 or 22 hours of the day in the plant working on critical problems.

When the installation of all four machines was completed, only one gun at a time was used on each side of the car to make all 32 welds. Ray had found that only one roller was needed bearing against the rocker. Photographs of the machines after installation appear in Exhibit 5. By this time the line was running at 49 to 50 cars/hour and the air cylinders had to be used to allow incremental movement of the machine

carriage. Ray recalled that the objective in running only one machine at a time per side had been to leave the idle machine free for maintenance and as a standby.

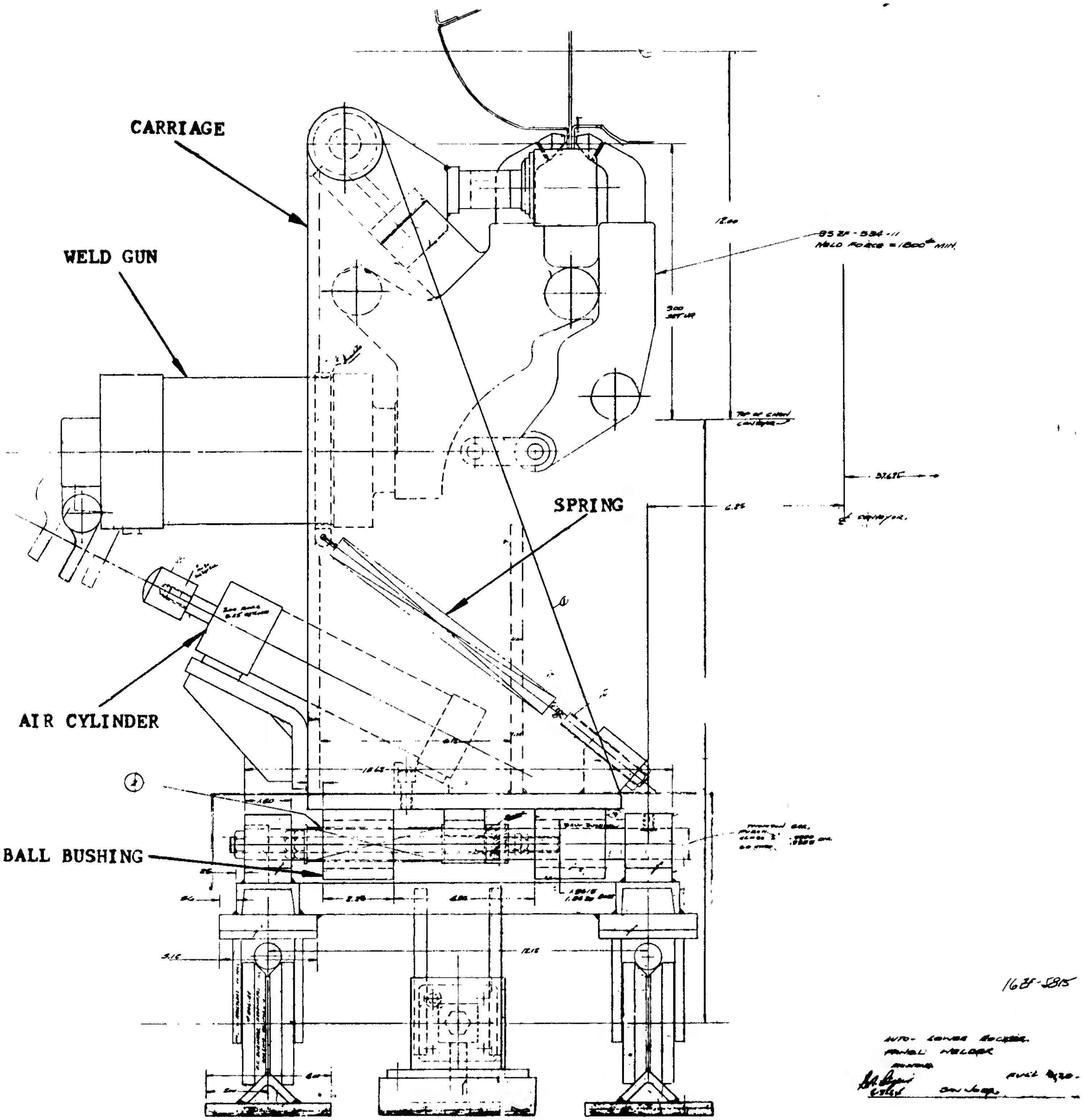
About the middle of 1965 all four machines were placed in continuous operation. Each machine now put in 16 spots on 4 inch centers, consecutive welds being made by alternating machines. This change allowed the cables and electrodes to run cooler, resulting in longer electrode life, and allowed the air cylinders to be used only as cushions, no incrementing being needed. Ray had first thought of changing to this method of operation about six months earlier, when he saw how violent the motion of the machine became at high speeds. However, his suggested change met with objections; it was thought that some spots might be missed. Several months later an electrician again suggested changing over to the simultaneous use of both machines per side, but again many people in the plant thought this scheme would never work satisfactorily. Finally, the foreman on the job brought the matter up again, saying that he personally would put in by hand any spots the machines missed. This show of conviction resulted in a go-ahead for Ray and Bill to begin the changeover, which required new electrical sequencing circuitry and quite a bit of readjustment. When this was completed, however, performance was satisfactory.

One operating problem still remained to be solved. Compression of the springs as the weld gun moved on its shaft with the car resulted in a retarding force on the body of considerable magnitude. When the machines were first installed, the spacer, which holds each body until a 12 inch gap is established between the skids, was

located just before the weld pit. However, the retarding force of the welding machines upset the 12 inch spacing. Ray explained that a gap of more than 12 inches slowed the production rate, while a lesser gap resulted in complaints from the union. To solve this problem the spacer was moved to a new location past the pit. With this change, the car being welded was pushed along by the (single) car behind it, as well as by the chain beneath its own skids. This extra push helped to give evenly spaced welds. However, if a car was late in coming off the transfer table onto the line, the car being welded would again be slowed and the welds would be too closely spaced. (Further, if the weld gun refused to open, it could seldom be broken loose without the extra push of another body behind.) Then when a car did come off the transfer table, it would rush forward and slam into the car being welded, the result again being mis-spaced welds. Car bodies are late coming off the transfer table when the assemblers have trouble bolting the body to its skids. Since this operation is carried out before the cars are actually on the line, a slight delay does not affect the line speed.

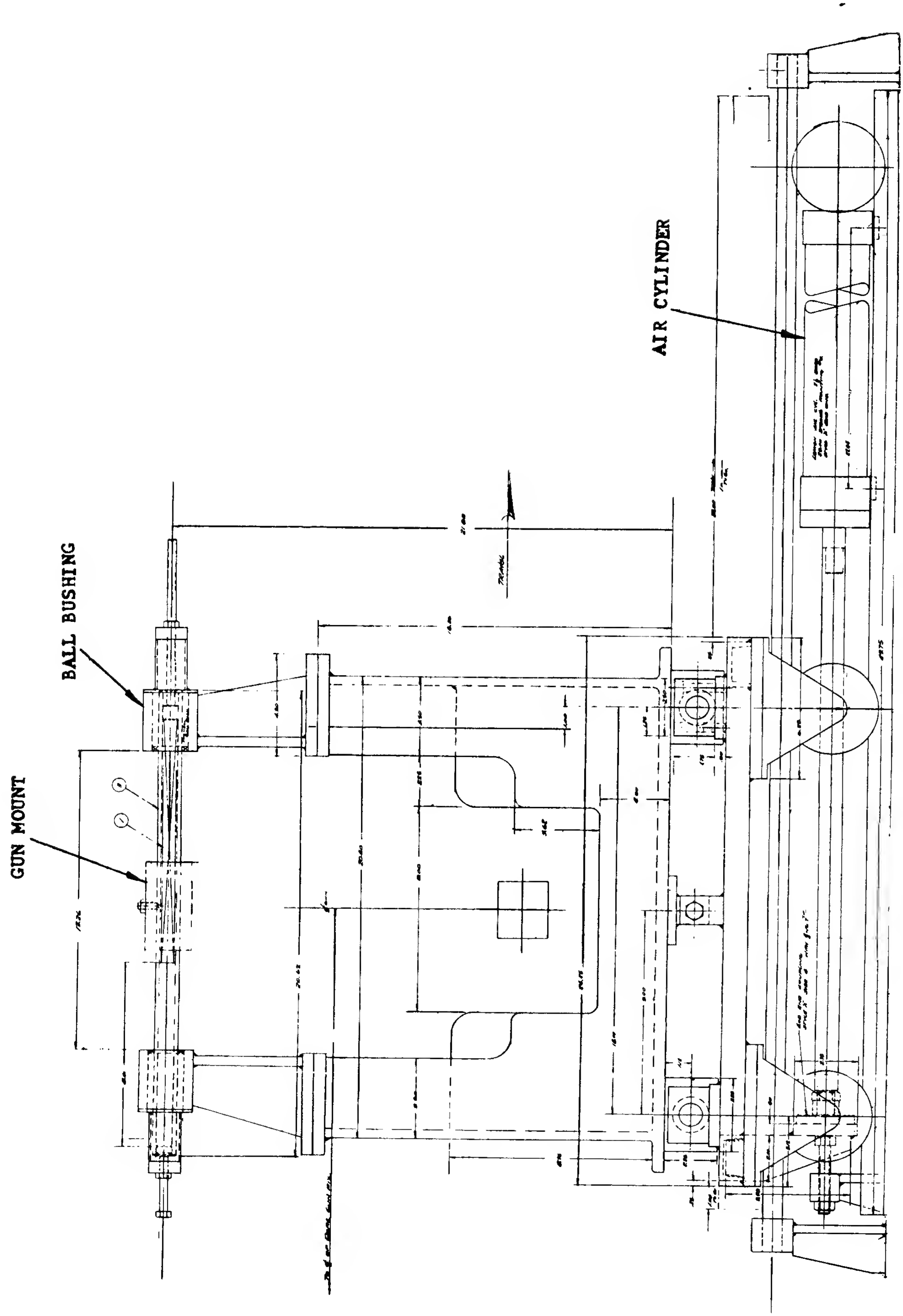
To alleviate the new problem, Ray and Bill added a limit switch and control circuitry to detect when there was no body following that being welded and to put in extra welds, ensuring a weld at least every two inches. Under these conditions the first machine on each side would put in welds on 2 inch centers instead of on 4 inch centers. The second machine would operate as usual, placing welds every 4 inches. This eliminated missed welds but sometimes one weld would be placed on top of another, resulting in questionable welds.

Ray felt that a positive means of moving the bodies past the welders was needed. About $5,000 had already been spent on purchased material and parts for the four machines.



Side View (Perpendicular to Assembly Line)

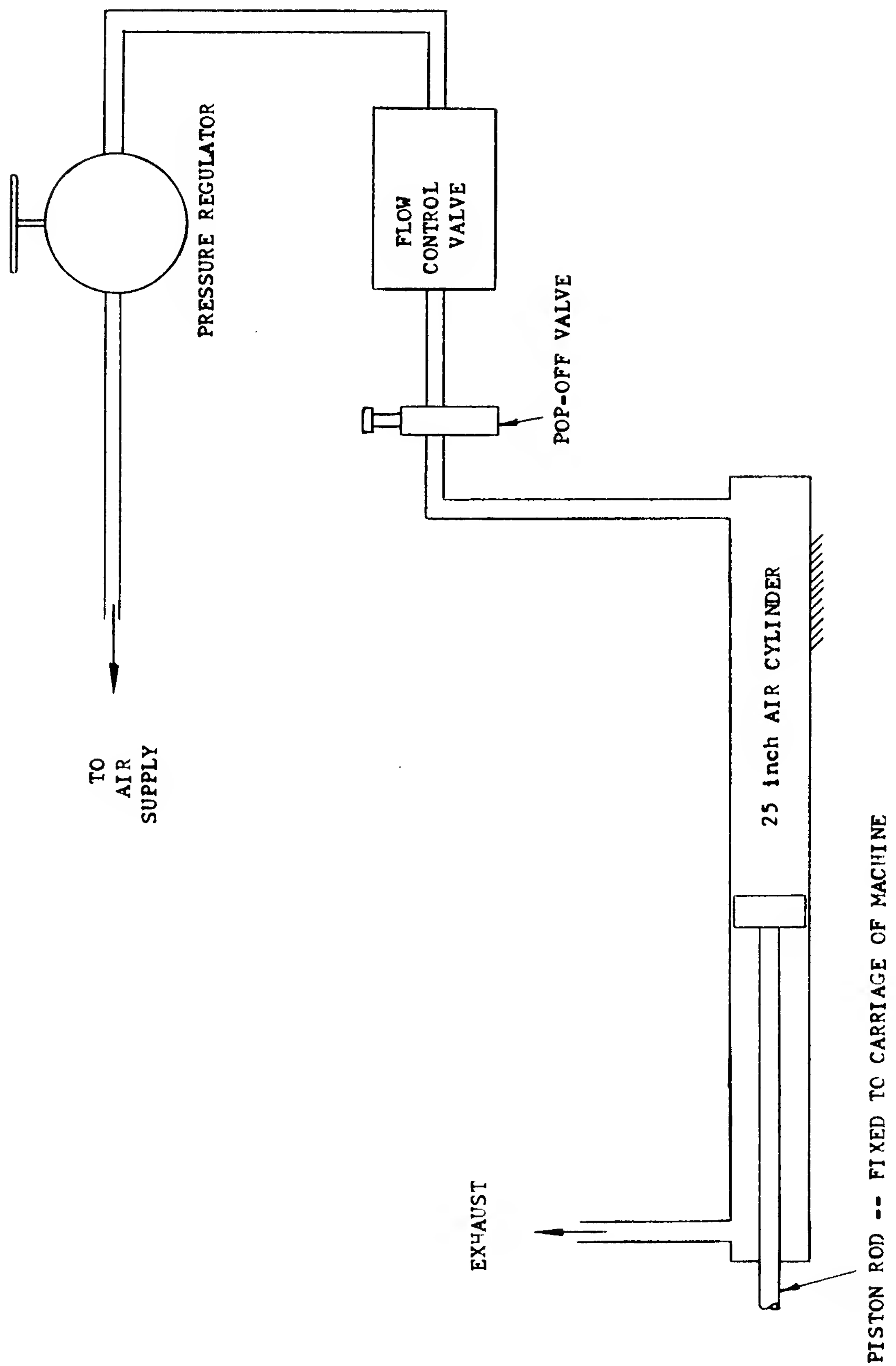
Layout of First Rocker Welding Machine designed by Ray Rodgers. Reduced in size.



View Parallel to Assembly Line. 2 of 2

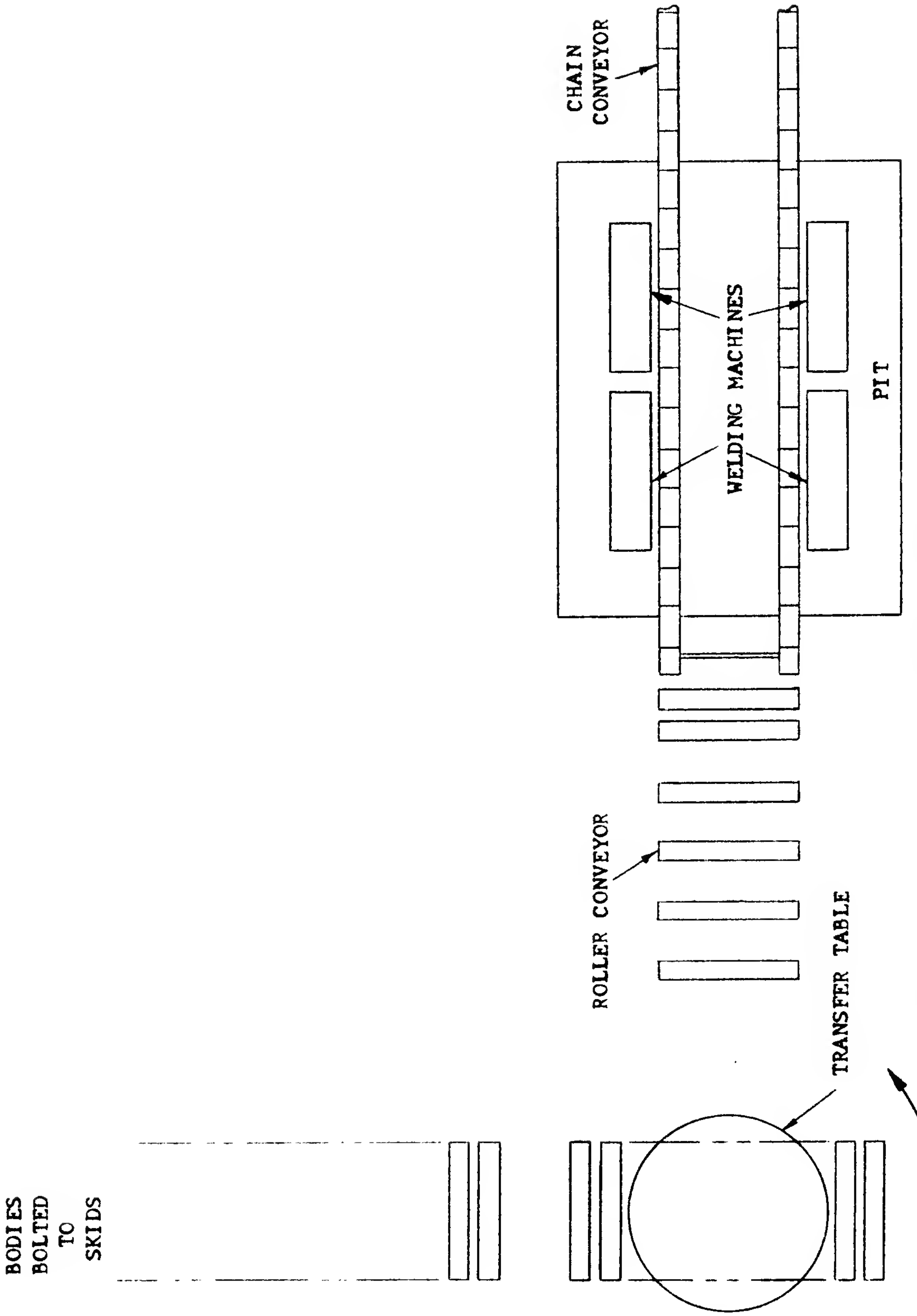
Exhibit 2

ECL 53B

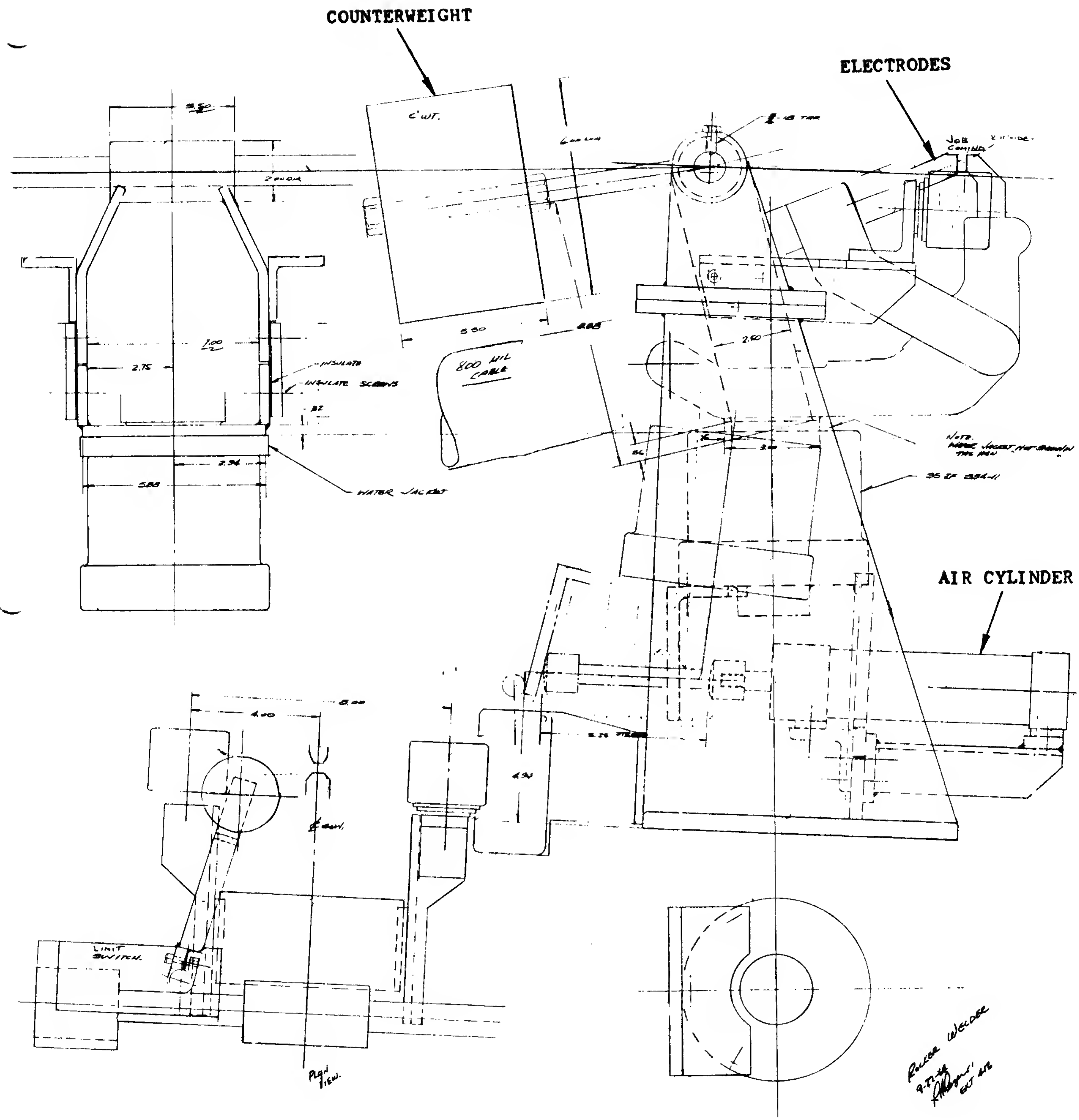


Schematic Diagram of Air Cylinder Circuit.

Exhibit 3

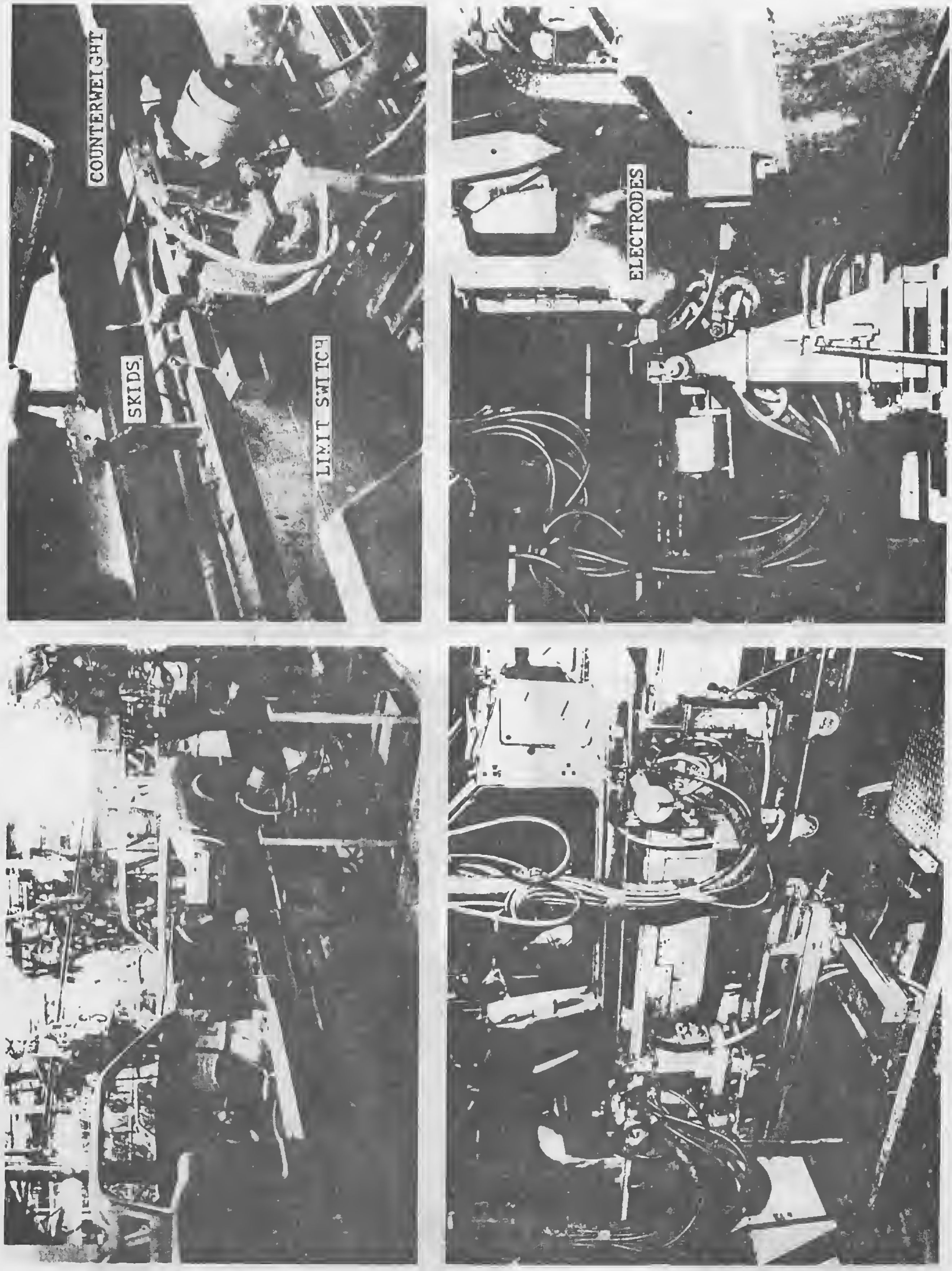


Floor Plan of the Rocker Weld Area. Not to Scale.



Overlay Drawing of Second and Final Rocker Welding Machine Designed by Ray Rodgers. Reduced in Size.

Exhibit 5

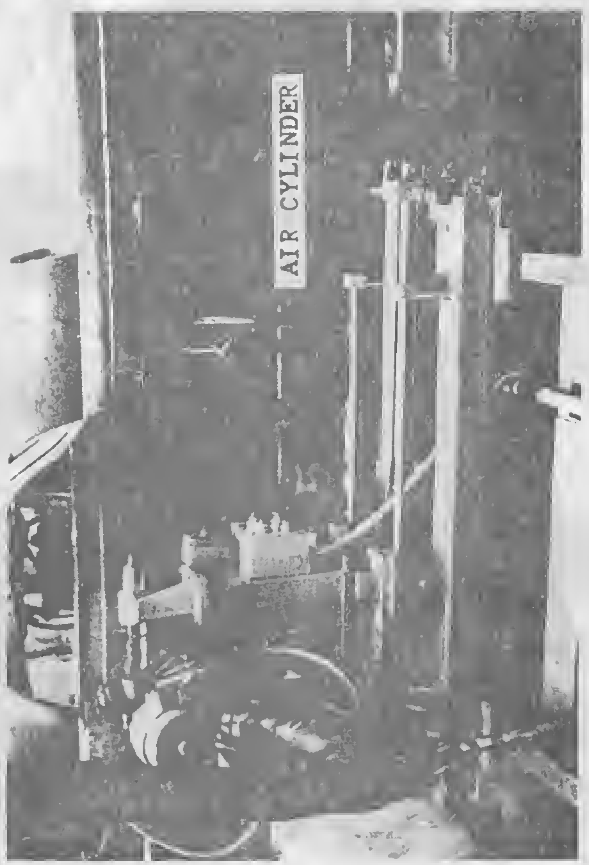


Rocker Welding Machines. 1 of 2


BALL BUSHING


CABLES ARE FOR ELECTRICITY,
AIR & WATER. TRANSFORMERS
ARE OVERHEAD.


ELECTRODES


AIR CYLINDER

Design of an Automatic Welding Machine
At Ford Motor Company, San Jose, California (C)

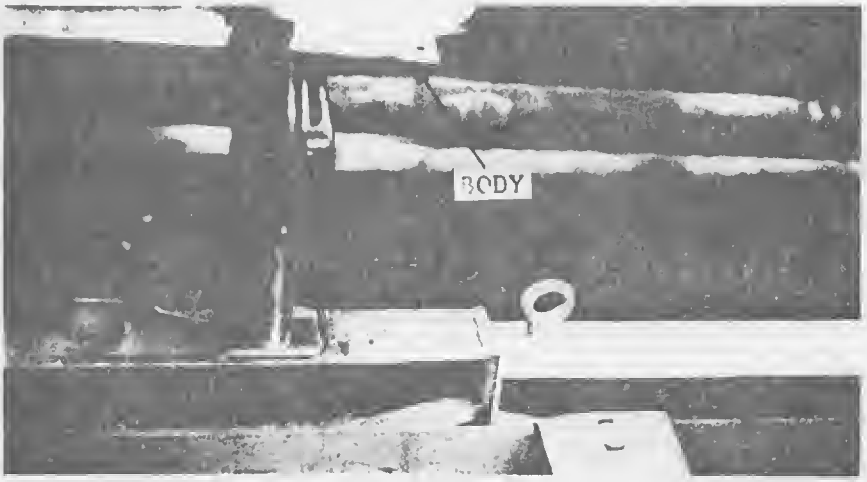
Ray Rogers considered and rejected three different methods for ensuring that car bodies would not be held back by the welding machines before deciding on a fourth. The first was to fasten the body being welded to the one ahead, so it would be pulled past the weld stations by the total frictional force on both skids. Ray tested this idea by clamping a pair of skids together with vise grips and holding back the body on the transfer table to see if evenly spaced welds would result with an extra body pulling but with none pushing. The body was welded satisfactorily and Ray went ahead and designed a coupler to fasten together a pair of skids. Exhibit I shows the ends of a pair of skids and the clamp Ray designed to couple them. An air cylinder actuates the movable jaw. Two of these clamps were to be employed, traveling on an endless chain beneath the conveyor. This chain would not have to be powered -- the clamps would be drawn along by the moving skids. But Ray rejected this scheme after determining that the variability in skid dimensions and their placement on the conveyor was too great to be accomodated by the jaws.

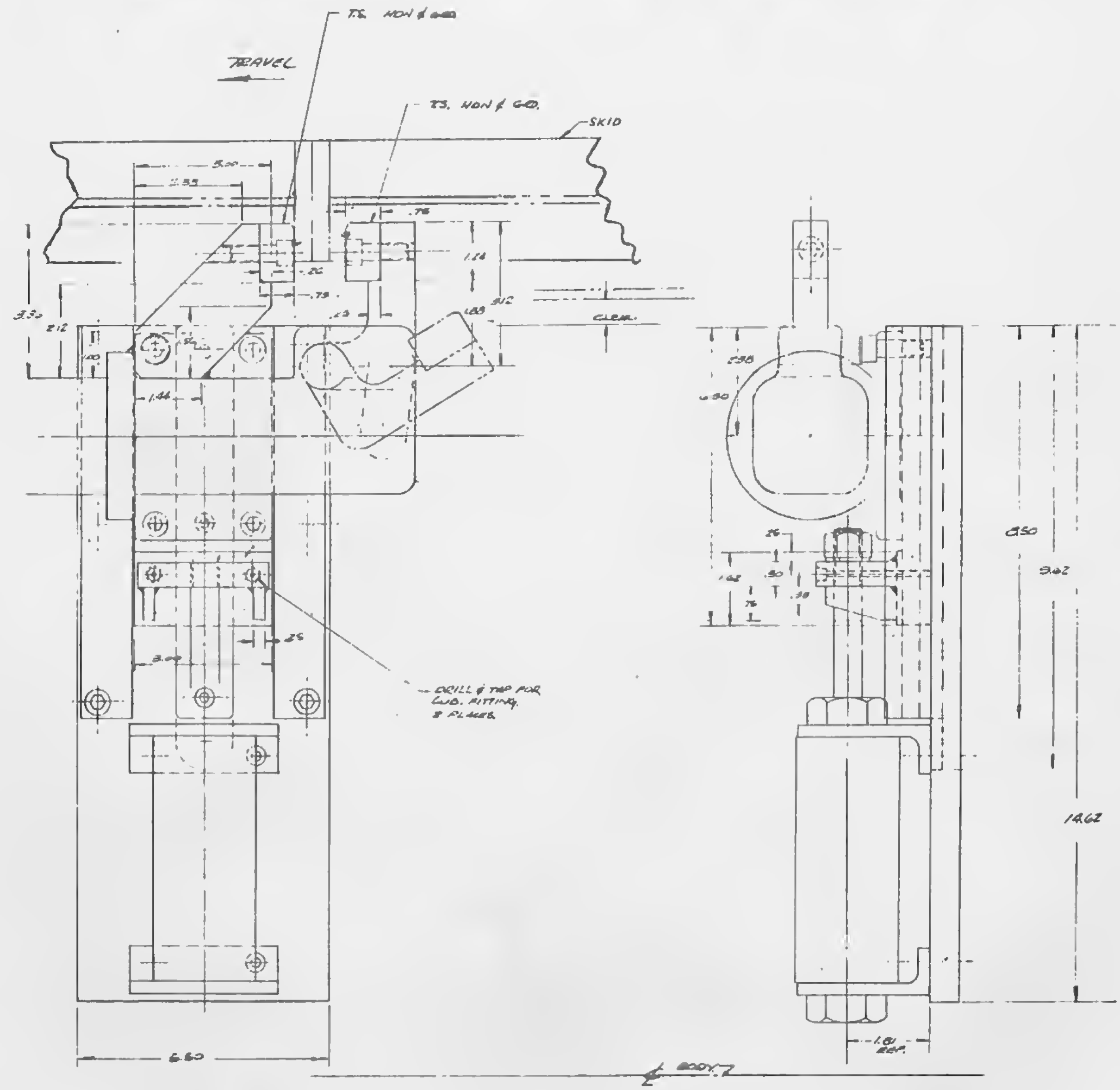
The second method he devised used a chain running down the middle of the line. It was to be driven by a shaft with a sprocket on each end which would mesh with one of the main conveyor chains. The auxiliary chain would carry dogs, one of which would bear against the front cross-member of the car body. The cars would be positively moved through the weld area, but Ray was unable to see how the skids could be stopped for spacing without something breaking.

A third scheme also used a chain running down the middle of the line carrying dogs to push on the front crossmember. However, this time Ray proposed to drive the chain with an air motor, as shown in Exhibit 2. The air motor drives a gear reducer through a chain and sprockets, also giving a reduction, to get suitable dog speeds. Ray finally disregarded this design because it would be impossible to vary the speed of the line by more than a few cars per hour and still get adequate torque from the air motor.

Near the end of 1965 Ray decided to resort to a device employing a cable cylinder to push the cars through -- again via a dog bearing against the front cross-member. A cable cylinder is an air or hydraulic cylinder within which a piston moves. Instead of a piston rod, however, one end of a nylon covered cable is attached to each side of the piston. Ray was familiar with these cylinders, made in various lengths by Tol-O-Matic, Inc. of Minneapolis, and he decided that an air operated cylinder 17 feet in length would be a practical means of moving the cars through the

weld area. The cable cylinders are described in Exhibit 3 and Ray's application to his design is shown in Exhibit 4. The design was completed in December 1965 and the device was installed in May. It operated as planned and Ray felt it had solved the spacing problems.

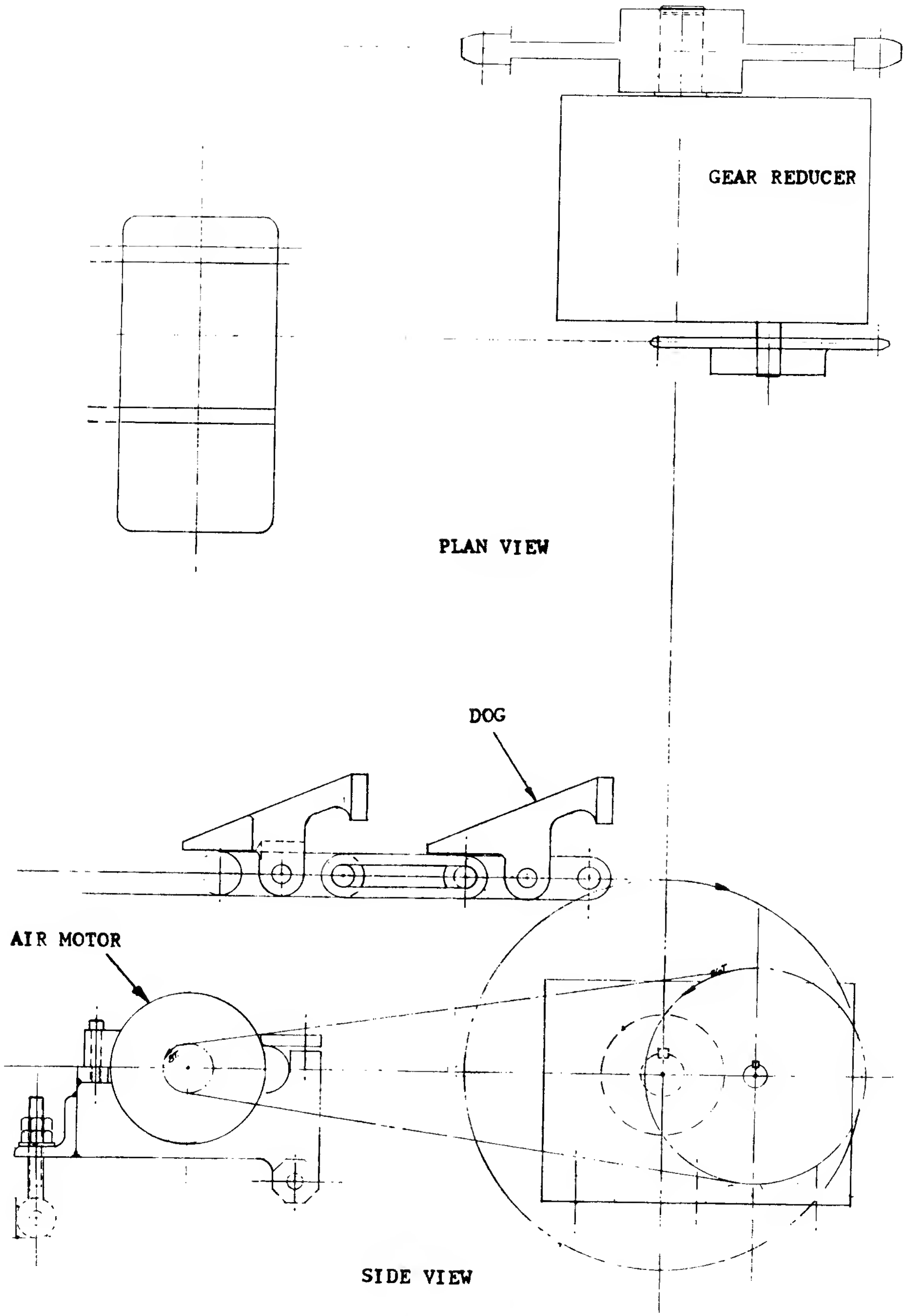




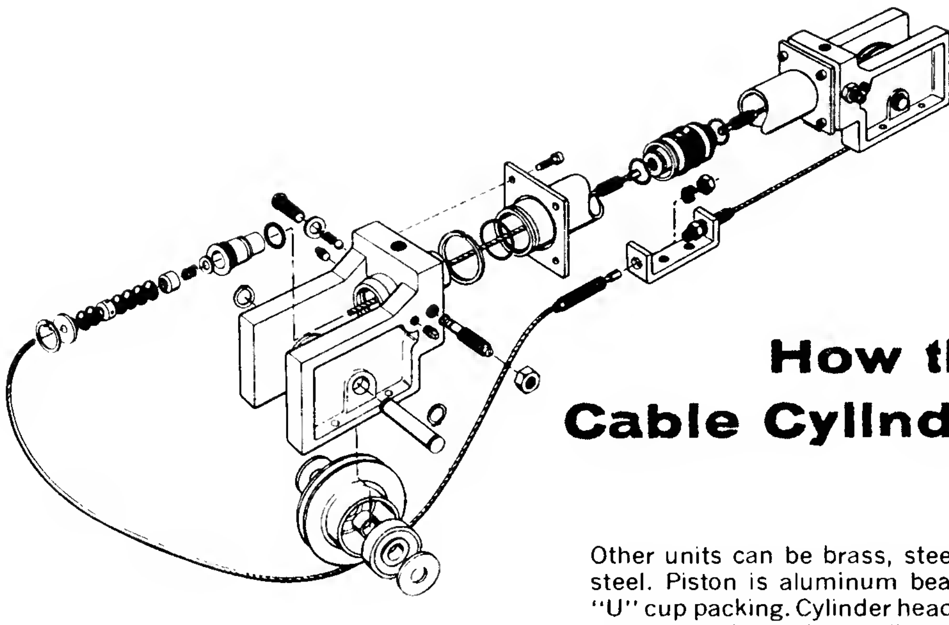
PLAN VIEW

SIDE VIEW

The Coupler Ray Rodgers Designed to Connect a Pair of Skids. The Top Picture Shows the Ends of Two Skids on the Chain Conveyor.



Air Motor Driven Chain with Dogs Designed by Ray Rodgers.



How the Cable Cylinder works

Drawing shows construction and operation of the Tol-O-Matic Cable Cylinder. Pneumatic or hydraulic pressure applied to one side of the piston moves it within the cylinder, pulling the cable around the pulley to impart desired motion to the driven mechanism through the attaching bracket.

Cable Cylinders are ruggedly built. The cylinder is brass tubing for the 1″ units and steel for the 6″ and 8″ units. Other units can be brass, steel or hard chrome plated steel. Piston is aluminum bearing alloy with standard "U" cup packing. Cylinder heads are cast of heat treated impregnated aluminum alloy to seal from leaking. The 1″ unit has a special design "U" cup to seal the nylon-coated steel cable. All other units are equipped with a double set of "V" packings. A drain chamber between the "V" packings permits returning to the reserve oil tank any oil that leaks by the seal—making Tol-O-Matic cable cylinders suitable for use in sanitary applications. Precision grooved pulleys machined to fit the radius of the cable and equipped with sealed ball bearings (over 1″ bore, 1″ has roller bearings), reduce friction and give maximum load capacity.

The Tol-O-Matic Cable Cylinder makes the designer's job easier. It can be located to satisfy the design need without concern over where to allow room for a long projecting rod. It is light, compact and structurally self-contained. It mounts by the two cylinder head pieces with no other support required.

Rotary motion is easily achieved. The cable can be extended to wrap around and turn a drum, or it can be threaded through a machine. Accurate positioning is easily achieved.

A wide range of performance is available. Force applied to the driven device can range from less than 20 pounds for a 1″ Cable Cylinder operated at 25 psi up to 5000 pounds for an 8″ Cable Cylinder at 150 psi. (See table on facing page.) The 150 psi is the maximum continuous pressure rating for pneumatic operation. Hydraulic rating is 200 psi, with a 2″ high pressure model going to 500 psi.

The nylon coating used on the cable acts as a cushion, a lubricant and a bearing surface—increasing cable life as much as 3000%. Cushioning devices at each end of the cylinder eliminate shock, provide smooth operation and assure long service-free life. Cushions are adjustable on all except the 1″ unit.

The Special Weapons Department of the U.S. Air Force has ordered cable cylinders with special packings and successfully operated them at —65° F.

Let Tol-O-Matic engineers show how the Cable Cylinder can help solve your design problems. Any specific inquiry will get a prompt, technically competent reply.

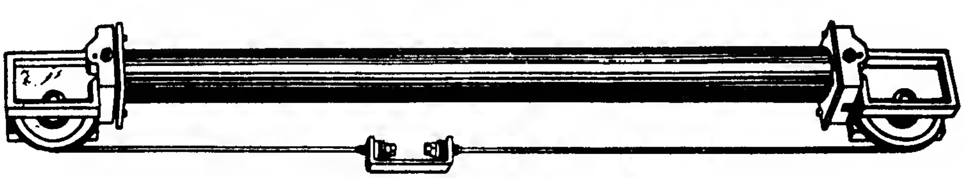
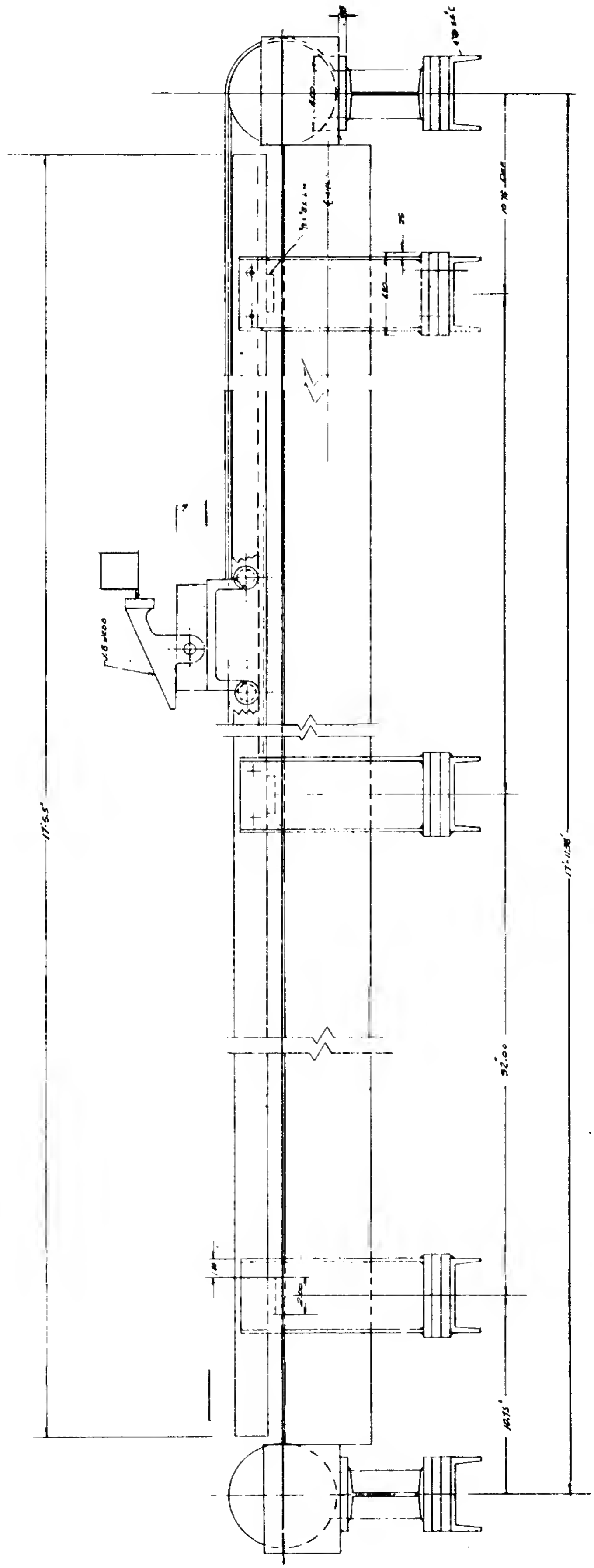


Exhibit 4

ECL 53C



Cable Cylinder Pusher Designed by Ray Rodgers.

The existing process had a production gun welder sitting on a scooter below the body, controlling a heavy spot weld gun higher than his shoulders. He was required to move the gun along the length of the flanges to proper spacing, keeping pace with a moving assembly line. The scooter needed a metal plate area. This would become oily and the operator could not maintain traction for his heels to keep up with the line movement. This would cause improper spacing of spot welds and operator complaint. Fatigue and inefficiency were constant results.

With the introduction of the new Mustang a pit area was created where the operator could stand upright and, with the gun counter-balanced overhead, weld the lower flanges. Ray and Bill were assigned the project to replace this manpower by engineered automation.

Ray and Bill were two of a total of 14 engineers in the Process Engineering Department. This department was responsible for planning of tooling and facilities as needed by production assembly people. One of the responsibilities of process engineers assigned to each production department in the plant is to act as trouble shooters. When the parts of the cars or trucks do not fit together correctly or when some of the parts do not function properly, process engineers must determine the cause of each problem and correct it. They also design special purpose production line machinery and modify commercially available machines to suit their needs. The Process Engineering Department works in cooperation with the Industrial Engineering Department, which is responsible for the most efficient allocation of work duties, and the Plant Engineering Department, which handles maintenance and repair of machines and equipment.

The San Jose Assembly Plant was completed in 1955. Trucks and Passenger cars were built in separate halves of the plant under one roof with similar departmental arrangements. They consisted of metal body construction, painting, trim (locks, glass, instrument clusters, ornamentation, radios, heaters, etc.) and chassis and final line assembly (brakes, axle, engine, steering, power controls, seats, gas fill, starting and power testing, and required repairs). About 3,200 people were employed at the plant, which could produce 288 cars and 168 trucks per eight/hour shift. Two production shifts were operating. Ray Rogers and Bill Fleming were assigned work responsibilities primarily in the Body Construction Department.

Ray was a specialist in automated equipment design. He had accumulated the equivalent of about three years engineering course credits in evening classes and began his career as a job shop tool designer. Bill Fleming also had had several years of engineering credits; his experience included work with the Bell Telephone Company as an electrician and with Ford Motor Company as an electrician in the Plant Engineering Department. Transferred to Process Engineering, he advanced from Body Process Engineer to Weld Engineer. Both engineers had begun learning for their speciality in directed school study. They had also devoted uncounted hours in self-training by text study and in developing their current talents.

Confronting Ray and Bill on this automation assignment was the development of welding equipment which would respond to varying thicknesses of metals, pace changes of unit travel, heat build-up of the weld gun, and variation of flange heights

to the gun in the weld area. To describe the actual weld conditions, imagine two metal thicknesses lapped together passing between two welding electrodes of a weld gun. This gun had to produce (per car) 32 welds spaced 2.00 inches apart. The third model Mustang, a convertible, had thicker metal and required unique weld settings which increased the complexity of design.

The Mustang had no separate body and frame, as in larger car models such as the Ford Galaxie, and was referred to as "unitized construction". The main structural strength was in the floor fabrication, which was comprised of formed sheet metal panels welded together to include the mounting areas of engine, floor, and body base. It was the side area of this body floor structure with which this welding application was concerned. Welding completed the assembly of frame and body. The flanges of side metal were located at the two outer bottom areas of the car between the front wheel opening and the rear wheel opening (commonly referred to as the rocker panel area). For the hardtop and fastback models the two thicknesses of metal were .060 inches and .090 inches, requiring one weld setting or schedule control. The convertible with its additional flange thickness for more top-less strength required twice (or dual) weld strength settings or schedule controls to overcome the increased weld resistance. The average metal combination was the outer body rocker metal of galvanized steel .060 inches thick welded to the floor side of mild steel .090 inches thick. Occasional reinforcement braces increased the metal thickness by .036 inches. The additional mild steel side sill panel on the convertible added .090 inches over the above.

Such spot welds were commonly made by a weld gun with two copper electrodes which clamp together like pincers on the metal to be welded. A weld gun is shown in Exhibit I. Process sheets for the rocker weld operations on the hardtops appear in Exhibit 2. The "Dual Schedule" note for the weld guns meant they were to be capable of welding different thicknesses of steel requiring different weld times. One of the engineers at the plant had seen automatic rocker welding machines operating at Ford Plants in Chicago and Dearborn but he told Ray that the machines gave a lot of trouble even though the maximum thickness of steel being welded was only .120 inches. The electrodes of the gun would occasionally become welded to the rocker due to fusing of the galvanizing zinc to the gun tip. When this happened, the gun would refuse to open at the end of a weld cycle and would be torn loose from its mount.

Ray also knew that the machines would have to be located on the assembly line at a point where cars moved continuously. During hand welding of the rocker the operators on each side used two guns, one for the first 16 welds, the second for the remaining 16 so the guns would not overheat. Therefore, Ray planned to use two welding machines on each side of the car. Each would move a single portable weld gun through a series of weld cycles. For each weld cycle the gun would clamp onto the rocker, weld, hold without welding for a period of time, and then release.

Just before the rocker weld operation, the car bodies came off an earlier line upon which the basic body shell is tack welded together. Leaving this earlier line

the body shells were complete except for front fenders, hoods, trunk lids, and doors. The rocker panels (floor side to body side) were in place, ready to be welded. Each body was bolted to two 16 foot long I-beam skids which ran along the under-sides of the body beneath the floor pan. Two men would bolt the bodies to the skids, then a short roller conveyor carried the assembly to a transfer table which turned it through 90° and ejected it to another set of spinning rollers. Six of these rollers formed the first 10 feet (approximately) of the line where the rocker welding was performed. Photographs of a body entering the line appear in Exhibit 3. The six rollers accelerated the body to the speed of a floor level chain conveyor. From this point on, the bodies were carried with skids resting on the chain links. In normal operation there was no gap between successive skids until they were separated by the "spacer" -- an arm which restrains the assembly while chain links slide beneath its skids until the body ahead has moved 12 inches onwards.

The thickness of the metal to be welded determined the time required for each spot. The numbers of cycles of 60 cps current Ray and Bill used for these times were:

	Convertibles	Hardtops
Squeeze of the electrodes for metal compression	12	12
Weld for electron flow	30	20
Hold for fusion time of metal	12	12

Ray and Bill knew that each skid was 16 feet long, that they were separated by one foot and that the speed of the line was expected to be 42 to 52 cars/hour. They also knew the numbers and spacing of the welds to be put into each car. Each spot weld

on a convertible took almost one second, and Ray could see that there would be time for a single gun to weld each rocker. However, he still planned to use two guns on each side of the car to avoid overheating.

Ray knew that the machines he designed would have to index the guns into position once they had cleared obstructions in the front wheel opening and likewise that the guns would have to index out of the way to clear the rear wheel openings. The rocker flange metal height dropped 5/8 inch from front to rear and the rear-end surfaces were displaced an inch outward from the front-end. The machine would have to accomodate these location changes as well as the variability between individual bodies and skids and their placement on the conveyor.